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HIBERNATION AND REJUVENATION, EXEMPLIFIED BY NORTH AMERICAN HERBS.

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(Continued from the May Issue.)

A thick horizontally creeping rhizome is also exhibited by *Sanguinaria*, but all the internodes are very short, and of the same thickness throughout; lateral branches are frequently to be observed, and there are many roots, all of the nutritive type; on the other hand the cortex and the pith of the rhizome contain large deposits of starch. At the stage of rejuvenation in the early spring the erect flower-bud is the first to appear, with the blade of the single leaf wrapped around the scape (fig. 41); the leaf does not attain its full size until the plant is out of bloom, and it persists until the close of the summer. In *Dentaria*, a very small genus, but with rhizomes of several distinct types, we have a long, horizontally creeping rhizome in *D. diphylla* (Fig. 42); the internodes are thick, and the scale-leaves fleshy, each subtending a bud with a slender root proceeding from its base. Only a very few of these buds grow out in the same year, and the lateral shoot then begins with a scale-leaf, or the bud develops directly into a flower-bearing stem. A very different structure is shown by *Dentaria laciniata* and *D. heterophylla*, in which the rhizomes represent a horizontal chain of long tubers, each representing the growth of one season; in these the subterranean foliage is only of very thin scale-leaves, barely visible. Only a single green leaf is developed, though not every year, and the flower-bearing stem, only one from the same tuber, is axillary; the roots

are very thin, and mostly in pairs from the axils of the scale-leaves. In *Dentaria tenella* the rhizome resembles that of *D. laciniata,* but is densely pubescent; in this species we notice the very rare case of small tubers becoming developed from the subterranean part of the long petioles. This type of growth, where the aerial shoots persist for only one season, is rare among the Dicotyledones, less so among the Monocotyledones: *Dioscorea, Polygonatum, Smilacina, Streptopus, Medeola, Oakesia,* and others. In *Dioscorea, Polygonatum* and *Smilacina* the internodes of the rhizome are very short, and the roots relatively thin. In *Oakesia sessilifolia,* on the other hand, the rhizome is more slender, and with the internodes very long; moreover the roots are relatively thick, containing large deposits of starch in the cortex. A very singular structure is exhibited by *Medeola Virginiana* L. The horizontal rhizome consists of an oblong tuber with three to four internodes with small scale-leaves, and with several slender roots proceeding from near the leaves. A large bud appears close to the apex of the tuber at the stage of hibernation, which in the succeeding spring develops into a tall flower-bearing stem with several whorls of leaves (four to five in each whorl), and with the umbellate inflorescence at the apex. A long, slender internode, terminated by a small tuber, becomes developed in the course of the summer from the apex of the old tuber, and judging from the position of the scale-leaves, which surround the base of the floral shoot, it appears as if the rhizome represents a monopodium, thus agreeing with *Paris* according to Alexander Braun and Irmisch.

While a typical, horizontally creeping rhizome with the internodes more or less stretched is represented by *Commelina hirtella* Vahl, we observe a very different structure in *C. Virginica* L., and *C. erecta* L. In these species the rhizome is very condensed, since no horizontal internodes are developed. The bud at the apex of the rhizome develops at once an erect shoot. In *Tradescantia rosea* Vent. the rhizome is horizontally creeping, the internodes stretched, and the roots, frequently two at each node, are relatively thick. The rhizome branches freely, and several branches may develop into floral shoots in the same year. The ramification

is monopodial until the first flowering, and the basal internode of each lateral branch partly fuses together with the main axis.

Croomia pauciflora Torr. has also a creeping rhizome with the internodes stretched, and with the long, somewhat fleshy roots developed from the nodes, thus resembling Oakesia. At the stage of rejuvenation the large, terminal bud, covered by only two membranaceous, scale-leaves, develops into a flowering stem, while a bud in the axil of the outermost scale-leaf grows out, and continues the rhizome, which thus represents a sympodium. This type of rejuvenation with only a single leaf (the younger stages) or a single floral stem is very frequent in plants with creeping rhizomes, but occurs, also, in connection with a vertical rhizome as in *Trillium*, for instance. In some of the *Orchidaceae*, *Orchis spectabilis* L., several species of *Platanthera* e. g. *P. clavellata* Michx., *P. obtusata* Pursh, *P. dilatata* Pursh, etc., the rejuvenation depends also upon the development of a single floral shoot, or a single leaf at the youngest stage. Only one large storage-root is in these developed beneath the shoot, beside one pair of slender, much longer nutritive roots. The stage of hibernation (fig. 45) shows the bud for the next year fully equipped with the same type of root-system as the floral shoot; between the floral shoot and the hibernating bud is a long, descending internode (S).

Much more frequent, however, is the type of rejuvenation, where each shoot persists for more than one year, and where several green leaves form a more or less distinct rosette around the base of the flower-bearing stem. In *Cimicifuga racemosa* for instance, the stout, horizontal rhizome consists of relatively short internodes, covered by large, membranaceous, scale-leaves; the secondary roots are strong, of quite a considerable length, and contain starch. A large bud terminates the rhizome, and at the stage of rejuvenation it develops into a tall, flower-bearing stem with mostly two or three large, green leaves at the base. Characteristic of *Cimicifuga* is the appearance of a small bud in the axil of the innermost green leaf, and this bud, although remaining dormant for several years, continues to develop very short internodes with scale-leaves in the manner of a dwarf-shoot.

In *Heuchera Americana* L. the creeping rhizome bears several thick roots of the storage-type, and they are amply ramified. A flower-bearing scape and several green leaves develop from the terminal bud, and several of the leaves persist throughout the winter. This type of hibernation and rejuvenation is frequent among the Dicotyledones with horizontal rhizomes. In *Hepatica triloba* Chaix var. *Americana* DC. the rhizome is vertical, and seldom branching; the terminal hibernating bud is always situated close to the surface of the soil, and is surrounded by several membranaceous, scale-leaves, besides that the green leaves from the preceding year's growth form a rosette around the bud. The stage of rejuvenation is marked by the development of several solitary flowers borne on slender scapes, while the foliage appears a little later. Regarding the seedling Hildebrand has described this, and it is interesting to notice that the plumule develops several scale-leaves before the green, three-lobed appears; in *Anemone nemorosa, A. blanda, A. narcissiflora*, etc., the plumule is kept beneath the surface of the soil, and the first leaf is aerial and shows already the final leaf-structure.

Horizontal rhizomes are also very common in the *Gramineae, Cyperaceae* and *Juncaceae*, besides several *Iridaceae*, etc. Most frequently the shoot is terminated by the inflorescence; but in the genus Carex the ramification is sometimes monopodial, so that each shoot represents an apical tuft of leaves with the flower-bearing stems proceeding from the axils of the leaves of the previous year. In *Tripsacum dactyloides* L. the very stout rhizome is almost above ground; in *Iris verna* L. and *I. cristata* Ait., the structure of the rhizome resembles that of *Podophyllum*, consisting of tuberous-thickened internodes alternating with slender ones. The stout vertical rhizome of *Symplocarpus foetidus* (L.) Nutt. represents a monopodium; in the very early spring one to several, almost sessile inflorescences, partly surrounded by membranaceous, scale-leaves, appear close to the apex of the rhizome. The apex itself, however, is purely vegetative and develops into a large rosette of green leaves, persisting until the fall. The stage of hibernation shows the rhizome with

remnants of the withered leaves, some of which subtend buds, containing the flowers for the next spring.

While thus the rhizomes themselves exhibit very distinct, external structures, the hibernating buds may also develop in a very different manner: as a lateral, purely floral and a terminal, purely vegetative shoot, when the ramification is monopodial, or into a combination of both, when sympodial. The stage of rejuvenation frequently appears as a repetition of the growth, which we have observed at the younger stages of the plants, sometimes even including the seedlings. The very earliest development of the rhizome may be looked for during the first or second year of the seedlings; in no other way can we feel assured that the subterranean stem, we have before us, is a primary structure, a true rhizome, instead of some lateral shoot, a stolon for instance. In rhizomes, which ramify, the branches always show the same structure as the main axis, the same type of internodes, slender or thick, short or stretched, and furthermore the same kind of leaves, membranaceous, sheathing or scale-like, etc., while in stolons the structure differs considerably from that of the main stem.

While the rhizomes s. s. are mostly developed by the plumule, the pseudo-rhizomes represent a combination of the hypocotyl, the persisting bases of the aerial shoots with their buds, and sometimes the primary root. Hj. Nilsson, who proposed this term, has given an enumeration of dicotyledonous plants, exhibiting this structure, among which are several species of *Paeonia, Orobus, Sedum, Agrimonia, Viola* (caulescent), *Campanula,* etc. Many of the North American herbs possess this type of rhizome, and it is especially frequent in the *Papilionaceae, Compositae,* etc. We have seen, how such rhizome may begin already during the first rejuvenation in *Baptisia tinctoria* (Fig. 32), where the primary root persists, where the contractile hypocotyl draws the cotyledonary buds down into the ground, and where these develop into aerial shoots with only the basal internodes persisting. These stem-bases in connection with the hypocotyl thus represent a pseudo-rhizome and the stage of rejuvenation thus depends upon the development of a number of axillary shoots. In *Cunila* (Fig. 29) the shoots are al-

ready to be observed during the fall as small fleshy branches with scale-leaves.

A somewhat complicated structure is exemplified by *Ludvigia alternifolia* L., and the habit of this plant is remarkably well illustrated by the seedling in the course of the first summer. The cotyledons are epigeic, and subtend no buds; the hypocotyl is long, erect, and the shoot is purely vegetative; the primary root is long, and becomes distinctly swollen at the base, forming a fusiform tuber during the first summer; secondary roots, about six in two rows proceed from the lower part of the hypocotyl, at a short distance from the tuber. The first stage of hibernation shows us only the base of the hypocotyl with the slender secondary roots and the tuberous part of the primary besides a small, scaly bud situated between the secondary roots. This bud is adventitious, and develops into an aerial shoot during the first rejuvenation. A little later on the root-system becomes changed, since the primary root-tuber dries up, becoming substituted by two or three lateral ones of the same structure, originating from some of the secondary roots of the hypocotyl. The future stages of hibernation and rejuvenation show a steady increase in the number of the slender, secondary roots, and consequently also of the tuberous, besides of the hibernating buds; the individual may live for about five or six years, becoming fertile already in the second year. Large specimens may show as many as fifteen fusiform roots, all occupying a horizontal position, and being of a different age, one or two years. The number of hibernating buds may aggregate about eight in such large specimens, but, as a rule, only one or two floral shoots are developed. The subterranean axis thus consists of the persistent part of the hypocotyl, bearing the roots and the buds, in other words a typical pseudo-rhizome. It seems strange that the tuberous roots, which last only from the latter part of the summer until the next spring, are covered by many layers of cork, and contain so much thick-walled hadrome; otherwise the structure is that of a storage-root, the secondary cortex and the parenchymatic rays in the stele being filled with starch. The root-structure is thus very different from that of the large storage-roots of *Cicuta* and *Archemora*, although these

plants grow associated with *Ludvigia*. Regarding the hibernating buds in *Ludvigia* these represent shoots rather than buds; the axis is relatively thick, but the leaves, apparently opposite, are membranaceous and scale-like.

In the perennial *Oenothera linearis* Michx. the stage of hibernation is very different from that of *Ludvigia*, described above. In this species of *Oenothera* the pseudo-rhizome is also very short, and bears several tuberous roots from one to about five, of a globular shape, and of a dark-brown color. But the hibernating shoots represent relatively large rosettes of green leaves, and numerous long, white, secondary roots proceed from the base of these rosettes. In large specimens with remnants of five floral shoots as many as ten to fifteen rosettes may be observed during the winter.

According to Nilsson storage-roots occur in several plants with pseudo-rhizome e. g. various species of *Paeonia, Dahlia, Sedum, Asclepias*, and *Salvia patens* Benth. Stolons s. s. on the other hand, are absent. Likewise the true rhizomes the pseudo-rhizomes may persist and remain active for many years.

As a primary structure tubers and bulbs are exceedingly well represented in the Monocotyledones, but rare in the Dicotyledones. We have seen the tuber becoming developed already at the seedling-stage in *Arisaema*, and the growth continues in the same manner until the tuber becomes terminated by the inflorescence; from that time the growth of the tuber becomes continued by a bud, developed in the axil of the first green leaf, thus the original monopodium becomes changed to a sympodium, exactly as in most of the monocotyledonous rhizomes (*Iris, Uvularia* etc.) Very characteristic structures are exhibited by the tubers in the *Orchidaceae;* they may represent separate shoots (*Aplectrum, Tipularia, Calypso, Calopogon*), or simply the swollen base of the flowering stem (*Liparis, Microstylis*), or finally as in *Arethusa* the swollen base of the flowering stem and a tuberous internode, belonging to the subterranean axis. In *Aplectrum* and *Calypso* the tubers are sometimes connected with branched rhizomes of exactly the same structure as we know from *Corallorrhiza*, and it is interesting to notice that in *C. odontorhiza* Nutt. the basal internode of the flower-

bearing stem forms a roundish tuber, borne upon the apex of one of the coral-like shoots. In *Aplectrum hyemale* (Muehl.) Torr. the subterranean stem is horizontal, partly slender, and partly tuberous i. e. the growth of each year results in the development of a slender, horizontal stem of mostly four internodes, and an ascending tuber of c. six internodes. The root-system is of long, slender roots proceeding from the basal internode of the tuber. All the leaves of the slender and tuberous part are membranaceous, scale-like or sheathing, with the only exception of a large, green leaf appearing close to the apex of the tuber, and this leaf hibernates. In the course of the following spring the inflorescence appears, developed from the axil of the membranaceous leaf beneath the green one. A very small dormant bud may be observed at the apex of the tuber, and being purely vegetative the complete axis of slender and tuberous internodes thus represents a monopodium. The hibernating stage shows the large, green leaf and several membranaceous leaves at the swollen base, the roots, and the horizontal, slender stem passing into a tuber from the preceding year. The rejuvenation depends upon the appearance of the inflorescence during the spring, and the development of a large bud in the axil of the second membranaceous leaf (counted from below) of the tuber. which grows out as a slender, horizontal shoot continuing the growth and direction of the entire subterranean axis.

In *Tipularia discolor* (Pursh) Nutt. the tubers show exactly the same structure as those of *Aplectrum*, but the slender internodes between the tubers are hardly to be seen, since they are so exceedingly short, and only three are developed. Hibernation and rejuvenation are marked by the same structures as in *Aplectrum*, and the single leaf persists through the winter. *Calypso borealis* Salisb., shows the same growth as *Aplectrum* and *Tipularia*, and likewise the latter the slender internodes, one or two, are very short. The tuber consists only of two distinct internodes, with the single flower developing from the axil of the second membranaceous leaf (counted from below), and with the green leaf beneath the minute apical, vegetative bud; a large bud situated in the axil of the lowermost membranaceous leaf of

the tuber will continue the growth of the subterranean axis. Characteristic of *Aplectrum, Calypso* and *Tipularia* is thus: the single, green leaf persisting through the winter; the apex of the tuber being a dormant, vegetative bud, and the inflorescence consequently lateral; the coral-like rhizome occurring beneath the tuber in *Calypso* and *Aplectrum,* but absent from *Tipularia;* the last genus shows, on the other hand, the remarkable root-structure with a velamen distinctly developed, although the plant is terrestrial. A very different structure is represented by *Calopogon pulchellus* R. Br., although the tuber and the few, very short, slender internodes between resemble those of *Tipularia.* But in *Calopogon* the tuber consists only of two internodes, the apical tapering into a very small shoot with one membranaceous and one green leaf, surrounding the base of the terminal inflorescence. The bud to continue the growth of the subterranean axis is situated in the axil of the second scale-leaf of the tuber (counted from below). The roots are confined to the slender internodes. Branched tubers may occur, and the lateral tuber has then been developed from a bud in the axil of the first leaf of the tuber, which otherwise stays dormant. With the exception of the coaetaneous appearance of the inflorescence and the green leaf the rejuvenation exemplified by the tuber resembles that of the genera described above, *Aplectrum,* etc.

In *Arethusa bulbosa* L., as mentioned above, the tuber consists of two internodes, of which the apical represents the base of the floral scape. At the stage of rejuvenation the old tuber is borne upon a long, slender, vertical internode, and the floral shoot arises from a cavity on the frontal part of the apical internode. This cavity is already at the time of flowering visible at the base of the floral scape, and it surrounds a bud, which is actually situated in the axil of the single green leaf. This bud is the one that will continue the growth of the axis, and its lateral position is also indicated by its first leaf being an adorsed prophyllon. From the external appearance of the floral shoot of *Arethusa* at the time of flowering we should not expect such rather complicated structure to be hidden within the long, tubular leaves. Nevertheless above the prophyllon and the succeed-

ing membranaceous leaf a long slender internode is developed, passing into a tuberous internode with a green leaf subtending a bud, and terminated by the flowering scape, with the basal distinctly swollen. With regard to the root-system there are generally six long, slender roots developed from the base of the floral shoot i. e. from the base of the long internode above the prophyllon.

Liparis liliifolia Richard shows a more simple structure of the vegetative organs. At the time of rejuvenation the floral shoot appears close to the base of an old tuber, globose and with no remnants or scars from leaves. The floral shoot begins with an adorsed prophyllon, followed by a few, mostly two, membranaceous leaves preceding the two large green ones, which surround the terminal, floral stem. By removing the leaves we notice the swollen base of the floral stem, and a bud belonging to the axil of the innermost green leaf, but partly enclosed within a cavity at the base of the swollen stem. The roots, mostly six, are slender, and proceed from the base of the tuber. Characteristic of *Arethusa* and *Liparis* is thus the participation of the floral stem in forming the tuber; in *Liparis*, as a matter of fact, the entire tuber represents the basal portion of this stem; furthermore the cavity at the swollen stem-base partly enclosing the hibernating bud is also peculiar to these two genera. While tubers are well represented in this family (*Orchidaceae*), not a single genus has been observed, so far, to develop bulbs.

Tubers of the first order, developed from the plumule itself are very rare among the Dicotyledones, but we observed such in *Dentaria laciniata* (Fig. 33) as described above. Formed by the hypocotyl, on the other hand, primary tubers are known from *Collinsonia*, *Scrophularia nodosa* (including the epicotyl), *Cyclamen*, *Umbilious*, *Eranthis*, several species of *Corydalis* etc. In *Dentaria laciniata* the rhizome of the mature plant consists of a horizontal chain of oblong tubers, each representing the growth of one year. In the other genera, mentioned above, the primary tuber persists as a single more or less irregularly tuberous body so long as the plant lives.

Tubers of secondary order, developed at the apex of stolons are infrequent among the Monocotyledones, some few

Cyperaceae: *Scirpus maritimus* L. *Cyperus rotundus* L., and *C. phymatodes* Muehl.; *Haemadoraceae*: *Lachnanthes tinctoria* (Walt.) Ell.; *Alismaceae*: *Sagittaria;* *Marantaceae*: *Maranta arundinacea* (L.) In *Fuirena squarrosa* Michx. the rhizome produces dimorphous shoots: flower-bearing stems with stretched internodes, and, alternating with these, tubers, consisting of only one internode, and with the apical bud remaining dormant; large deposits of starch were found in these tubers. The plant is perennial, but it is not seldom to find small specimens developed in the autumn, which lack these tubers, and which do not persist through the winter. In certain *Gramineae* the subterranean internodes of the culms become tuberous, for instance, in *Melica, Panicum, Ehrharta,* and Hackel considered these tubers to represent water-reservoirs. In *Avena bulbosa* Willd., on the other hand, Seignette found a large quantity of starch in its tubers.

Among the *Dicotyledones* tuberiferous stolons are not infrequent, in the *Labiatae,* but otherwise they are mostly known from small genera; *Hydrocotyle* (*H. Americana* L.), *Circaea, Trientalis, Cynthia,* or from a few species of the larger: *Oxalis, Solanum, Helianthus, Senecio* etc. Stolons of this type appear frequently at the seedling-stage, from the axils of the cotyledons, and as stated above, they may represent the only part left of the mother-plant at the close of the first season. While the slender internodes gradually wither during the winter, the tuber persists, develops roots in the early spring and produces a new individual. It is very frequent, that the seedling itself does not attain the stage of flowering, while the tuber may grow out as a flowering shoot already in the first year after hibernation. The tubers do not, as a rule, persist for more than one season, but they give rise to axillary stolons, becoming terminated by tubers, and repeating the growth in the next season. Moreover the new individual generally shows the habit of the seedling to produce stolons, thus the distribution of the plant over a large area, and, at the same time, the abundance of individuals becomes effected by means of tuberiferous stolons. A unique type of stolons is represented by *Apios tuberosa* Moench. which we have described in this

journal (May 1924). The long, horizontally creeping stolons consist of many internodes, several of which increase in thickness so as to form tubers, arranged at intervals like beads. These tuberous stolons persist in an active condition for several years, giving rise to terminal, aerial shoots "vines," or to lateral, becoming stolons. The roots are always confined to the tuberous portion of the stolons; they are sparingly branched, and bear bacterial tubercles.

Tubers of second order thus represent some very distinct structures: the basal, cauline of the *Gramineae*, the sessile of *Fuirena*, the bead-like in Apios, and the typical tubers terminating the stolons in the *Labiatae*, etc. Those of the *Gramineae* and *Fuirena* take no direct part in the vegetative reproduction; they are simply storage-organs. In the others they are not only storage-organs, but they perform also the function of contributing to the distribution of the plant.

The typical bulb represented by the *Liliaceae* (*Allium, Lilium, Erythronium, Ornithogalum,* and *Amaryllidaceae Hymenocallis, Narcissus, Zephyranthes*) is very seldom to be found in the Dicotyledones. As described by Irmisch the structure of bulbs shows several modifications with regard to the position of the floral scape being terminal or lateral; the number of the nutritive leaves, varying from one to many, and their shape, the base being very narrow, or broad, enclosing the axis more or less completely.

The bulb is most frequently, if not always, a primary structure, and in several genera it may be traced already from the seedling-stage, before the first hibernation. But for several years the rejuvenation depends only upon the development of a single, green leaf, and a bud. The root-system is very uniform, the long, slender, unbranched roots being of the nutritive type. In *Erythronium Americanum* Ker. the stage of flowering is preceded by a purely vegetative growth for several years, where the young bulb produces several lateral stolons beside a green leaf. These stolons are developed in the early spring; they consist of a single, but long internode, of which the apex becomes a bulb in the course of the summer. The internode of the stolon dies off very soon, and the secondary bulb thus becomes separated from the mother-plant, giving rise to a new indi-

vidual in the succeeding spring. When the plant has attained the flowering stage, no stolons become developed, the shoot dying off completely. We have, thus, in *Erythronium Americanum* the rare occurrence of a bulb producing bulbiferous stolons.

Among the Dicotyledones true bulbs are known from a very few plants, and *Oxalis* is the only genus, so far as we know, where they occur. In *Oxalis violacea* L. the bulb-structure appears already at the seedling-stage, and in mature specimens the bulb itself differs in no respect from the typical one of the Monocotyledones. But in this species of *Oxalis* bulbiferous stolons become developed from the bulb, following the same course of hibernation and rejuvenation as we have seen in *Erythronium*. Moreover a large storage-root may become developed beneath the bulb (Fig. 36), but this is no constant character. We have observed such water-storage-roots in mature as well as in younger specimens, and they are only to be found in the spring. Arechavaleta, Chauvel, and Hildebrand have described the occurrence of such bulbs in various species of *Oxalis*: *O. Macachin* Arech., *O. Bowiei* Lindl., *O. cernua* Thunbg., *O. Coppoleri* Tod., and *O. rubella* Jacq.

Bulb-like structures, on the other hand, are exemplified by several Dicotyledones. We have mentioned *Viola papilionacea, Dentaria diphylla, D. bulbifera, Dicentra Cucullaria,* and *Hydrophyllum Canadense,* where such structure occurs in the rhizome of the mature plant, and sometimes even to be traced from the seedling-stage. As secondary structures they have been observed in *Lithophragma tenella* Nutt. (figs. 43-44), upon the subterranean stem-portion, but the bulb-scales are borne upon a distinct, elongated axis. In *Claytonia Chamissonis* Esch. similar bulbs are developed at the apex of long stolons, already at the seedling-stage, from the axils of the cotyledons, and a corresponding structure recurs in *Epilobium palustre* L. In the genus *Saxifraga* sessile bulblets occur at the base of the aerial shoot and in the axils of the inflorescence of *S. cernua* L., *S. bulbifera* L. and *S. granulata* L. Similar aerial bulblets are known also from *Claytonia parvifolia* Moc., and from *Dentaria bulbifera* L. But whether subterranean or aerial these bulb-like shoots or

buds are of great importance to the distribution of the plants, even if the aerial are, sometimes, replacing the flowers as in the arctic-alpine *Saxifraga cernua*, and in the far southern alpine *S. bulbifera*.

We have seen from the preceding pages that stolons may be terminated by tubers or bulbs, but the most frequent structure is, that all the internodes are slender, thus the apical as well as the lateral buds develop into aerial shoots without any previous formation of tubers or bulbs. In *Uvularia perfoliata* the rhizome of the mature plant is vertical, very short, and entirely concealed by the scale-leaves; the roots are relatively thick, very long, and sparingly branched. The stage of hibernation is merely represented by the rhizome with some buds and the root-system. At the time of rejuvenation the large, apical bud of the rhizome grows out as an erect, flowering stem, while some buds, generally two, situated in the axils of the scale-leaves develop into very long, slender, rootless stolons with stretched internodes and with long, tubular, membranaceous leaves; the first leaf of the stolon is an adorsed prophyllon, thus indicating the lateral position of the stolon. In the course of the summer the stolons cease to grow and roots begin to develop at the apex, and attain a considerable length during the fall; at that time the stolons, with exception of the apical bud, have withered, and the apex with the roots are then in the position to hibernate. With regard to the flowering stem, this dies down to the ground, when the fruits have matured, but the rhizome itself may persist for a year longer, since there is generally a large bud visible at the base of the flowering stem, and a new system of roots becomes developed before the winter sets in. *Uvularia perfoliata* thus represents a plant with typical stolons, and with an exceedingly short, vertical rhizome. A similar structure recurs in *Maianthemum Canadense* Desf., but the stolons of this plant persist for several years, and remain in connection with the mother-shoot. While thus the stolons may be readily distinguished from the shoot, that bears them, in *Uvularia* and *Maianthemum*, it is rather a difficult matter to decide, whether we have a rhizome or a stolon before us, when we consider the subterranean stems of several *Gramineae*, *Cyperaceae* and

Juncaceae. In some of these the subterranean stems resemble stolons throughout, while in some others they look more like rhizomes. We have spoken of a rhizome in *Tripsacum*, because the stout, horizontally creeping stem resembles the typical rhizome of *Acorus*, all the leaves being aerial, green. One might, on the other hand, feel tempted to define the scaly, subterranean shoots of *Leersia Virginica* Willd., several species of *Muehlenbergia*, *Uniola latifolia* Michx. and some others, as stolons rather than rhizomes, although their actual position is identical with that of other creeping shoots in the *Gramineae*. According to Warming (1923) rhizomes do not seem to occur in the *Gramineae*, but in the *Cyperaceae* and *Juncaceae;* stolons are according to this author very frequent in the *Gramineae*, besides in the two other families. How to draw the distinction is another question. Warming himself (l. c. p. 165) held the opinion, that no absolute distinction could be drawn between stolons and rhizomes.

But we have seen in *Uvularia* and *Oakesia* how the stolons originate in the former: from the axils of the scale-leaves, and the rhizome in the latter: from the plumule itself. Moreover the stolons in *Uvularia* deviate in structure considerably from the short rhizome, that bears them, while the branches of the creeping rhizome of *Oakesia* differ in no respect from the main rhizome. Such comparison may be applicable also to the *Gramineae*, *Cyperaceae* and *Juncaceae*. In *Tripsacum*, for instance, we find a typical rhizome, creeping, extensively branched, and destitute of stolons. A similar structure recurs in *Panicum virgatum* L. In *Leersia*, *Muehlenbergia* and *Uniola*, mentioned above, horizontal shoots develop from the axils of leaves belonging to a floral or vegetative shoot, of which the subterranean stem is exceedingly short, but amply provided with roots. These lateral shoots bear only scale-leaves, and they remain rootless until the succeeding spring. The young stages of many *Gramineae*, examined so far, show a corresponding structure with one or several lateral, creeping shoots becoming developed from the basal leaves of the primary. There is no indication of any horizontal rhizome, and the lateral shoots unquestionably represent stolons, to the same extent as those described

in *Uvularia.* The very long horizontally creeping shoots of *Spartina, Distichlis, Agrostis* and many other grasses are also stolons, according to our opinion. Moreover, we have in some genera: *Agrostis, Glyceria, Stenotaphrum,* etc., species of which corresponding, lateral shoots, but aerial and with green leaves, represent typical runners.

This type of stolons with the apex slender is frequent in the dicotyledons, and may be developed from the axils of the cotyledons, or from the basal leaves of the mature plant. Likewise the tuberiferous type these stolons may not persist for more than one season, leaving the apical bud to hibernate and produce a new individual during the next spring. Or they remain in connection with the mother plant for several years, branching freely, but retaining the structure of stolons until the apex develops into an aerial shoot. The aerial shoots may live for only one season, or, as for instance in some of the *Compositae,* the basal internodes may persist for several years. Stolons of this type may occur in genera, of which other species have tuberiferous stolons as for instance in the *Labiatae,* as mentioned above (*Lycopus, Scutellaria*); most frequently, however, they represent the only type characteristic of the genus: *Berula angustifolia* Mertens et Koch, (Warming 1876-1877), *Gratiola viscosa* Schwein., *G. aurea* Muehl. *Chelone glabra* L., *Lysimachia quadrifolia* L. etc. In some of the *Compositae* the stolons persist for several years, and develop into a rosette of leaves preceding the floral stem, which generally appears in the following season as in *Achillea millefolium* L. In *Coreopsis verticillata* L., on the other hand, the long stolons, rootless during the winter, hibernate in connection with the mother-plant, and develop immediately into a floral shoot without forming a rosette of leaves. *Aster divaricatus* L. has stolons of considerable length, but these are amply provided with roots, proceeding from the nodes. Many of the scale-leaves subtend buds, which grow out as stolons. The aerial shoot begins with some few, four or five, short internodes and small scale-leaves preceding the green ones, which are alternate, and not forming any basal rosette. There is generally a large bud visible in the axil of one of the scale-leaves, which grows out as a floral shoot during the next

year. Purely vegetative shoots are also devoloped from stolons, but they die down to the ground during the first season, apparently leaving no buds to hibernate. It is thus characteristic of *Aster divaricatus,* when compared with most of the other species of the genus, that stolons are so well represented, and that the flower-bearing stem is not preceded by any rosette of leaves, while purely vegetative shoots are developed from separate stolons.

It is interesting to notice that stolons are also represented by arctic and alpine plants, for instance in *Oxyria digyna* (L.) Hill (arctic and alpine), *Halianthus peploides* (L.) Fr. (arctic), *Stellaria umbellata* Turcz. (alpine), *Epilobium Hornemannii* Reich. (alpine), *Polemonium caeruleum* L. var. *villosum* (Rud.) Brand (arctic). *Pedicularis lapponica* L. *and P. capitata Adams* (arctic), and numerous *Gramineae* and *Cyperaceae* in both regions.

The runners are aerial, plagiotropous branches, developed from the axils of the leaves of an orthotropous, aerial shoot; they may consist of a single or many internodes; they may be terminated by a rosette of leaves, and subsequently by a flowering stem, or they may remain as purely vegetative shoots, monopodia. As compared with the stolons the runners represent a larger number of types, but they very seldom bear tubers or bulbs. *Antennaria neglecta* Greene may be mentioned as an example of the simplest type. In mature plants the stage of rejuvenation shows a rosette of spatulate leaves and a central flower-bearing stem; long, horizontally spreading runners become developed from the axils of the leaves of the rosette; they consist of several internodes, and the leaves are shorter and much narrower than those of the rosette; furthermore they are completely rootless. During the early part of the summer the rosette and flowerbearing stem die down to the ground, while the runners begin to form terminal rosettes, from which roots become developed; finally the other parts of the runners wither and the new rosettes with their roots and a central bud are left to hibernate. This type of runners is characteristic of the genus, and especially well represented by *A. Parlinii* Fernald, *A. plantaginifolia* (L.) Richards, *A. fallax* Greene etc. In *Erigeron bellidifolius* Muehl. the runners root freely

at the nodes before the new rosettes are developed, but otherwise the structure agrees with that of *Antennaria*. A very different type is, however, exhibited by *Erigeron flagellaris* Gray. The primary root and the leafy rosette persist for several years, producing long, slender runners with many small leaves subtending flower-bearing stems, and rooting at the apex, where new rosettes become developed; the runners branch freely thus many new individuals become developed from each plant. The arctic-alpine *Saxifraga flagellaris* Willd. has runners consisting of a single, relatively long internode terminated by a rosette; while the mother-plant dies after the first flowering, the new rosettes become provided with roots and winter over, but remain vegetative for a few years until the terminal, floral shoot appears. The development of runners does not begin until the plant has attained the flowering stage. In *Claytonia sarmentosa* C. A. Mey. the aerial shoot represents a monopodium; it consists of a rosette of leaves, which winters over, and from the axils of which flowering stems are produced in the succeeding spring. Runners of one or several internodes become developed from the axils of the leaves from the previous year, and form new rosettes. Secondary roots develop from the internodes of the runners. An interesting structure is shown by *Stellaria pubera* Michx.; while the plant is still blooming, a few erect purely vegetative shoots begin to develop, of which the leaves are always larger than those of the floral shoots. While the floral shoots die almost to the ground as soon as the fruits have matured, the vegetative shoots do not only remain active, but they continue their growth until late in the fall. At the close of the season these shoots have become closely appressed to the ground like runners, and winter over. At the stage of rejuvenation a number of flowering stems develop from the nodes of these runners, and the internodes gradually withering, a series of independent individuals is produced, repeating the structure of the mother-plant with floral and vegetative branches. Sometimes a few-flowered inflorescence may appear at the apex of the large, vegetative shoots, and although these flowers become developed much later than the others (those of the normal, floral shoots), they are nevertheless, perfect, and

sometimes even larger than the earlier ones. Furthermore the lowermost internodes of the floral shoots persist with some buds, and continue to grow in the manner of a pseudo-rhizome, thus *Stellaria pubera* is one of the few plants in which a pseudo-rhizome as well as runners are represented. A corresponding method of vegetative reproduction is to be observed in *Phlox divaricata* L. with the only exception that the runners persist for several years, continuing their growth and developing axillary shoots without becoming separated from the mother-plant.

It is characteristic of this type of runners that their foliage differs from that of the flowering stem by being generally smaller and narrow, except *Stellaria pubera*, where the leaves are much larger. Another type is represented by *Potentilla Canadensis* L., and several other species of the genus. The seedling of *Potentilla Canadensis* has hypogeic cotyledons, and the plumule develops at once into a runner-like shoot with the internodes stretched. In the mature plant the leaves form a rosette, from the axils of which long procumbent runners become developed. They consist of several long internodes, and there is a typical green leaf, two bracts, and a flower at each node; the flower is terminal, representing the apex of the long internode, while the runner becomes continued by another long internode developed from the axil of one of the bracts. The structure is as follows: The apex of the runner bears two small, rudimentary leaves with the stipules distinct, but the blade minute, bract-like; of these leaves the lower one subtends a short, erect, vegetative branch with only one large, typical leaf, while the upper one subtends a long shoot, the continuation of the runner; as stated above, the flower is terminal. The runners thus show a series of small, root-less shoots separated from each other by long internodes. In the course of the summer most of the shoots wither, while the long internodes remain active until the fall. At that time one of the apical shoots has begun to develop roots, and we notice that the small vegetative branch has not only increased in thickness, but has also begun to develop leaves. In other words a new individual is about to be formed, and during the winter this little plant is represented by a small tuber, bearing a rosette

of four to five typical leaves, and provided with several long, amply ramified roots; the long internodes of the runner have withered completely. The shoot of the mother-plant hibernates also as a rosette of green leaves devloped from the apex of the tuberous rhizome, thus representing a monopodium.

In *Ranunculus Cymbalaria* Pursh long runners are also developed from the rosette of the mother-plant. But these runners are monopodia, and numerous small rosettes of leaves are developed at the very distant nodes, rooting freely and developing several flowers. At the close of the first season the long internodes wither, and each rosette becomes an independent individual, which hibernates.

The genus *Hydrocotyle* incl. sectio *Centella* is an interesting genus from this particular point of view: hibernation and rejuvenation. It represents three types: one with tuberiferous stolons besides slender runners, another with rosette-bearing runners, and finally a third type, a creeping herb with the axis representing a monopodium, the inflorescences being axillary. Of these types *Hydrocotyle Asiatica* L. shows exactly the same habit as *Ranunculus Cymbalaria*. The runners are monopodia, and the secondary shoots consist of rosettes of leaves with axillary inflorescences, and root freely. The seedling has epigeic cotyledons, and a distinct hypocotyl; the slender primary root is not persistent, and becomes replaced by secondary roots proceeding from beneath the cotyledons; the first leaf of the plumule shows the shape typical of the species, oblong-reniform, repand-toothed. We have mentioned the tuberiferous stolons of *Hydrocotyle Americana*, but this species develops also long, creeping runners from the axils of the leaves of the upper part of the main stem. The foliage of the runners shows the same shape as those of the stem, but the petioles are much shorter. Although these runners bear several roots beneath the leaves, they hardly persist through the winter, inasmuch as we have never found any plants developed from hibernated runners, while the tubers produce new individuals in abundance. This species of *Hydrocotyle* has no rosette of leaves; the very slender stem is profusely branched, the branches thus representing runners above ground,

and subterranean, tuberiferous stolons. It is the only member of the family exhibiting this type of habit. So far as concerns the structure of the runners *Hydrocotyle Americana* forms a transition to another group of plants, where the runners do begin as axillary, cotyledonary shoots, and later on as lateral branches in the mature plant, but showing exactly the same structure as to length of internodes and shape of leaves as the main stem. This type of runners is exhibited by *Glechoma hederacea* L. according to Irmisch. All the shoots are aerial, and the leaves persists through the winter. At the time of flowering the shoots become somewhat erect, but when the fruits have matured, the axis becomes extended beyond the inflorescence, and grows out in a horizontal direction, representing a long, rooting runner. In other words the inflorescence in *Glechoma* is not terminal as in most of the other *Labiatae*, and the main axis as well as the lateral shoots develop as runners, profusely branched.

Among the Monocotyledones runners are poorly represented, and it is only in the *Gramineae* that these shoots are sufficiently distinct from the others, so as to be defined as runners; they occur in *Agrostis alba* L. var. *stolonifera*, *Glyceria maritima* Huds., *G. angustata* R. Br., *Festuca rubra* L. etc. The long creeping shoots of *Juncus repens* Michx. and *J. subtilis* Mey., may also be considered as runners..

Typical runners are thus mostly connected with rosettes of leaves as we have seen in *Antennaria*, *Erigeron*, *Saxifraga*, *Claytonia*, *Potentilla*, *Ranunculus*, and *Hydrocotyle* sectio *Centella*. Less characteristic are those of *Stellaria*, *Phlox* and *Glechoma*. *Glechoma* actually forms a transition to the group of plants, which is generally called "creeping herbs," which have no runners, but of which the branches are creeping, and all bearing the same type of leaf, as is characteristic of the species. This type of plants is represented by a number of Dicotyledones, of very different families, and mostly of some few species of large genera. But considered from the view-point: hibernation and rejuvenation, the creeping herbs do not show much of interest. The simplest type is represented by *Hydrocotyle umbellata* L., *H. verticillata* Thunbg., and *H. ranunculoides* L. f. where

the stems are monopodia, rooting at the nodes, and with one leaf and one axillary inflorescence at each node. In *Dichondra repens* Forst. the single, axillary flowers appear near the apex of the shoots; *Lippia nodiflora* Michx. and *L. lanceolata* Michx. have opposite leaves, and one axillary inflorescence at each node; in the terrestrial form of *Ludvigia palustris* (L.) the stems are creeping, the leaves opposite with axillary flowers. In *Lysimachia nummularia* L. the primary shoot grows out as a long monopodium with the opposite leaves persisting through the winter. The lateral shoots are either axillary flowers or vegetative branches of the same structure as the primary. *Coccocypselum repens* Sw. shows the same habit. The seedling has epigeic cotyledons, a short hypocotyl, but the primary root withers early, becoming replaced by several secondary roots, the first one proceeding from beneath the cotyledons, between these. The long epicotyl is ascending, and for a few months the shoot is erect. The mature plant, however, is creeping, the primary axis remaining as a long monopodium as in *Lysimachia;* the inflorescences are borne upon short, lateral branches; secondary roots become developed from the internodes of the branches, and new individuals become produced, when the posterior part of the mother-shoot gradually dies off. *Evolvulus nummularius* L. grows in the same manner, closely appressed to the ground, and the single flowers appear near the apex of the lateral branches; strong secondary roots are developed from the nodes, but only one at each node. Several species of *Veronica* belong to this type, and the stems show the same monopodial structure as described above. Finally the genus *Asarum* shows quite an interesting structure, and very distinct from those described above. The seedling of *Asarum Canadense* L. has a long primary root, sparingly ramified, an erect hypocotyl, and two epigeic, long-petioled cotyledons with the blades oblong-ovate; the cotyledons are held in an erect position, and the venation of the blade is distinctly palmate. The plumule may develop a green leaf in the first season, but generally it stays dormant until the succeeding spring. The first rejuvenation depends upon the appearance of cotyledonary buds, and the development of a scale-leaf preceding a green with the blade reni-

form. In the third year the primary root still persists, and the short, erect stem bears now two scale-leaves and one green; at the same time the cotyledonary buds are still dormant, and a bud has also appeared in the axil of the scale-leaf of the previous year. For a few years the direction of the stem remains vertical, and the primary root persists, but afterwards, when the secondary roots begin to develop, the stem becomes horizontal, and the primary root dies off. As already indicated by the young plant there is a regular alternation of scale-like and green leaves, which becomes continued in the mature plant. The stage of rejuvenation in the mature plant shows us three scale-leaves preceding two green ones surrounding the single, terminal flower. Moreover some lateral branches become developed from the axils of the scale-leaves from the year previous, while only one of the green leaves, the lower, subtends a bud; a long internode is visible between the last scale-leaf and the first green one, while all the other internodes are very short. From the seedling stage until the first flowering the axis represents a monopodium, but after that time the bud in the axil of the green leaf grows out into a flowering shoot of the same structure as the mother-axis, and a sympodium becomes formed. Several of the buds in the axils of the scale leaves grow out at the same time, thus a mature specimen may show an amply ramified stem, representing the growth of several years. In *Asarum Virginicum* L. and *A. arifolium* Michx. only one green leaf is developed each year, preceded by two scale-like. According to Eichler the European *Asarum Europaeum* L. shows the same composition of the shoot as *A. Canadense*, but the leaves are evergreen (as in *A. Virginicum* and *A. arifolium*), and the bud, which continues the direction of the mother-shoot, is situated in the axil of the upper green leaf.

Several other examples might be mentioned, especially from the suffrutescent, for instance: *Mitchella, Vaccinium Oxycoccos* L., *Arctostaphylos, Epigaea, Chiogenes, Linnaea, Pyxidanthera* etc. Among the Monocotyledones creeping plants are represented by several genera: *Eragrostis* (*E. reptans* Nees), *Catabrosa* (*C. aquatica* L.) Beauv. *Cynodon, Buchloe, Mayaca, Commelina, Heteranthera*, etc.

The rhizomes, the pseudo-rhizomes, the tubers, the bulbs, the stolons, the runners and finally the creeping stems, all of these structures indicate the perennial habit, taking an active part in the hibernation and rejuvenation of the plants. As storage-organs and at the same time representing an important means of distributing the plants, the rhizomes are well comparable to the tuberiferous or bulbiferous stolons; the runners perform the same function as the creeping stems. They are widely distributed among the plants, and to a very different extent. Moreover they are not connected with any particular type of floral shoots, as represented in perennial herbs. The very unlike distribution of these structures among the species themselves points towards the probability that they are fixed characters rather than epharmonic. For when we compare the actual conditions of the environment, these are identical and common to numerous other plants, even closely allied species, lacking such structures. Some indication of epharmonism seems to depend on the almost complete absence of bulbs and runners from the arctic and alpine regions. The nature of the environment must be decisive in this particular case. The geographical distribution of plants with bulbs or runners does not cover these regions. It seems also remarkable, for instance, that the sciaphilous plant-associations comprise the most extreme types of vegetative structures, with almost the only exclusion of the annuals. Moreover, we must remember that some very peculiar structures are retained by the mature plants. Some of these structures are undoubtedly fixed, since they appear so very plainly at the seedling-stage, just before the first hibernation, a period that hardly might have any influence upon the future habit of the plant, from an epharmonic point of view. We have seen that in certain species of the *Labiatae* stolons with or without tubers are developed from the cotyledonary buds before the first hibernation; still some of the species are closely related, and occupy the same soil. The species of *Hydrocotyle* described above are also interesting from this point of view.

With regard to the root-system the mature plants often retain the primary structure, that of the seedling. The fibrous, secondary roots replacing the primary, as shown al-

ready at the seedling stage of *Ranunculus abortivus* is a structure common to many Dicotyledones. The primary root developed as a storage-root very frequently persists as such through the whole life of the plant as for instance in *Claytonia Virginica* L., *C. Caroliniana* Michx., *C. lanceolata* Pursh, *C. magarrhiza* Parry, *C. arctica* Adams, *Panax quinquefolium, P. trifolium, Erigenia, Ipomaea pandurata, I. leptophylla, Phytolacca decandra, Chenopodium ambrosioides,* etc. In *Anemonella thalictroides* (L.) Spach the primary root shows already at the seedling-stage a distinct increase in thickness, forming a fusiform tuber, and it remains active until the next season, when it becomes replaced by a secondary root of same thickness; in mature plants the root-system consists of a cluster of tuberous roots. *Ludvigia alternifolia* shows the same structure of the root-system, and beginning already at the seedling-stage. The tap-root in *Aconitum uncinatum* L. persists as such until the flowering stage; when the fruits have matured, the individual dies off, except some short, thick stolons developed from the axils of the basal leaves. These stolons are terminated by a large, vertical bud with a tap-root of the same structure as that of the mother-plant, and new individuals are produced during the succeeding spring. In *Scrophularia nodosa* L. var. *Americana* Michx. the hibernating stage of the mature plant shows several long, swollen, more or less fusiform roots with slender apices, and with several lateral, thick branches; these roots grow in a horizontal direction, and are white, almost transparent. There is no rhizome s. s., but the basal internodes of the aerial stem persist, and some axillary buds winter over to develop into aerial shoots in the succeeding year.

Archemora rigida DC., of which the primary root shows a distinct increase in thickness before the first hibernation, retains this structure in most of the secondary roots during the succeeding years. An immature specimen, purely vegetative, and in its fourth or fifth year, has no rhizome in the stricter sense of the word, but only some very short internodes with remnants of leaves. At the stage of rejuvenation the root-system consists of two sets of secondary roots: several very long and slender proceeding from the very base of the shoot, and beneath these four to five thick, fusiform,

all of a white color. Most of the long, slender roots will increase in thickness during the summer, and become storage-roots with the apical portion dying off gradually. They will thus attain the same structure as the thick, fusiform, which had hibernated. When the plant has reached maturity, the aerial stem dies down to the ground during the fall, leaving only a large bud to hibernate, and a cluster of fusiform roots (Fig. 13). *Cicuta maculata* L. shows the same structure of the seedling as *Archemora,* and the same development of large, fusiform roots in older specimens. The stage of rejuvenation of the mature plant (Fig. 14) shows many long, slender roots above the fusiform, which have hibernated. When the fruits have matured, the stem withers, leaving a small bud in the axil of the basal leaves to winter over. But beside this little bud, there are two others, much larger, situated at some distance below. These large buds have a thick, short axis of several internodes, and provided with a root-system of their own: four thick, fusiform roots (Fig. 15). The destination of these buds is to develop new individuals, when they become detached from the mother plant during the fall; figure 15 shows the hibernating stage of one of these buds, which had become detached. The small bud, mentioned above, will evidently develop into a new shoot, but remain in connection with the old stem and the roots, several of which were still fresh and active. A similar structure has been described by Warming (1884) as characteristic of *Anthriscus silvestris;* in this plant, however, the primary root becomes a large taproot, and persists as such. The individual dies generally after the first flowering, but vegetative reproduction becomes effected by means of several basal buds, which drop off and develop new individuals. While still connected with the mother-plant these buds are provided with one or two thick storage-roots, exactly as in *Cicuta.*

Among the *Compositae* we observe a tuberous root and the development of basal, axillary buds in *Prenanthes alba* L., but we have not, so far, been able to find the seedlings. In young, purely vegetative specimens, the root is very thick and branched, the branches short, and each extended into mostly two long, almost filiform apices. At this stage only a

few green leaves are developed, besides some scale-like, and some basal shoots are already to be seen at the very base of the root. These shoots consist of one or two scale-leaves beside some few green ones, but with the blades ovate, and not lobed as the typical foliage. Moreover, each shoot has a long, thin root, and becomes detached from the mother-plant in the course of the summer. Individuals developed from this type of buds are numerous, and they represent an important means of vegetative reproduction. The long, slender root withers almost completely, leaving only the basal portion to hibernate, which at that time has already increased considerably in thickness and attained approximately the same shape as the root of the mother-plant, but in a smaller scale. We have thus in *Cicuta*, *Anthriscus* and *Prenanthes* a type of vegetative reproduction, where basal shoots become detached from the mother-plant, and produce new individuals; this type of reproduction is connected with a root-system of considerable size, at least so far as concerns the genera mentioned.

With respect to the Monotyledones the root-system shows but little of interest in the mature plants, since no increase in thickness takes place. In some of the *Orchidaceae*, notably our species of *Orchis* and *Platanthera* the root beneath the hibernating bud is quite thick, and more so than the others. This depends on its anatomical structure, which shows several central cylinders, instead of only one as in the other roots. Relatively thick storage-roots are exhibited by several species of *Commelina*, for instance *C. Virginica* L. and *C. erecta* L. the rhizomes of which are very short, condensed. In *Tradescantia rosea* Vent. and *T. pinetorum* Greene the rhizomes are long and horizontal, bearing two to three thick roots at each node; in the latter species these roots vary from oblong to fusiform terminated by a long, slender apex. Similar fusiform storage-roots occur also in *Weldenia candida* Schult. fil., proceeding from the basal nodes of the short, vertical rhizome. The thickness of the root of these *Commelinaceae* depends only upon the large number of parenchymatic strata, notably in the cortex. In *Uvularia perfoliata* the very short, subterranean stem bears a facicle of relatively thick roots, while in *Oakesia sessilifolia* with

the horizontally creeping rhizome the roots are more slender.

In comparing the root-structure represented by the perennial herbs at the stage of maturity, it is interesting to notice that several, very distinct types occur within the same genus, as for instance in *Claytonia, Panax, Oxalis, etc.*, in accordance with the structure of the subterranean stem, however. For in Claytonia the large-rooted species have no rhizomes, while in the species with fibrous roots, *C. parvifolia* Moc., and *C. asarifolia* Bong. a rhizome is well represented, vertical in the former, horizontally creeping in the latter. Only the bulbous species of *Oxalis* have a typical tap-root, and, as mentioned above, *O. violacea* multiplies to a great extent by means of bulbiferous stolons. There is sometimes a well marked correlation between the structure of the subterranean stem and the root-system viz., creeping rhizomes, and stolons have generally slender roots, while most of the short, vertical rhizomes, and several pseudo-rhizomes bear roots of the type "storage-roots." But with regard to the environment none of these root-structures appear to be dependent on any particular kind of soil; large-rooted species may be found in woods, fields, bogs, etc., but mostly in the low-lands. *Claytonia megarrhiza, Calandrinia pygmaea* and *Rhodiola,* are known from the alpine regions; *Claytonia arctica* Adams and *Rhodiola rosea* L. from the arctic.

Regarding the development of buds as a means of vegetative reproduction, distinction must be drawn between those which develop into shoots before they become detached from the mother-plant, and those, which in the shape of small tubers or bulbs fall off, and do not develop into new individuals until the succeeding spring. The first type is represented by *Archemora, Anthriscus* and *Prenanthes, as* described above. In these plants the buds have begun to develop leaves and are provided with roots before they become detached. The second type, tubers or bulbs, occurs in *Dentaria tenella* Pursh., *Cicuta bulbifera* L., *Polygonum Macounii* Small, *P. viviparum* L. (tubers); in *Saxifraga cernua* L., *S. granulata* L., *S. stellaris* L. var. *comosa* Poir., and *Claytonia parvifolia* Moc. (bulbs). In *Dentaria tennella* small tubers, single or in clusters of two to four, are developed along the subterranean portion of the long petioles of

the basal leaves, as well as in the axils of the cauline. *Cicuta bulbifera* has no bulbs, but tubers, consisting of two internodes, in the axils of the upper-stem-leaves. Similar tubers occur in the inflorescence of the two species of *Polygonum*. Small bulbs are as mentioned above,, known from *Saxifraga cernua* L., *S. bulbifera* L. and *S. granulata* L., where they occur at the base of the aerial shoot, besides in the axils of the bracts of the inflorescence; in *Saxifraga stellata* L. var. *comosa* Poir. nearly all the flowers are replaced by bulblets. Finally in *Claytonia parvifolia* Moc. several of the cauline leaves subtend bulblets. These buds, however, whether developed into shoots before becoming detached, or representing small tubers or bulbs to hibernate before developing any further these are axillary with the only exception of the tubers upon the petioles in *Dentaria*.

A very different type is the adventitious, where the buds occur notably upon the roots, seldom upon the hypocotyl, and very seldom upon the leaves. Of these the root-shoots are known from many trees and shrubs, but only from a small number of the herbs. Among the herbs *Cirsium arvense* (L.) Scop., and *Rumex Acetosella* L. are examples well known. While root-shoots generally substitute stolons and rhizomes, we observed a combination of both in *Lupinus perennis* L., *Pyrola aphylla* Sm., *Chimaphila umbellata* (L.) Nutt., and *Ch. maculata* (L.) Pursh. It is not uncommon to observe that the production of root-shoots in abundance results in the almost complete non-development of germinative seeds as for instance in *Convolvulus spithamaeus* L., and various species of *Apocynum*, *Asclepias*, etc. On the other hand, *Rhexia Mariana* L. and *Rh. Virginica* L., as described above depend solely upon root-shoots, so far as concerns their vegetative reproduction. We might also call attention to *Strophostyles umbellata* (Muehl.) Britton, of which the root-system remains active and produces numerous shoots in the third year after germination, while the aerial shoots die off completely in the course of the second year.

Adventitious buds upon the hypocotyl are known from only a few North American genera: *Linum*, *Hypericum* and *Linaria*. In *Linum* and *Hypericum* the development of shoots in this manner enables the plant to persist for several years

instead of but one, the species being typically annuals. With reference to the development of buds upon leaves *Tellima grandiflora* Dougl., *Cardamine pratensis* L., several species of *Drosera*, and *Malaxis paludosa* (L.) Sw. are examples well known.

These structures constitute the most important means by which the herbs become enabled to persist as perennials. They are very well expressed in the mature plants, but the real nature of some of these structures may not be understood unless we know their origin from the seedling-stage. In many instances the distinction between rhizomes and stolons cannot be drawn unless we know with certainty that the former represent the primary axis from the very beginning, and the latter branches of second order. We have seen how the plumule, sometimes in connection with the hypocotyl, may develop into a horizontally creeping rhizome as in *Podophyllum, Sanguinaria, Heuchera, Cimicifuga, Viola, Dioscorea*, etc., and remaining purely vegetative for several years. We have also seen how the plumule may develop into an aerial shoot, vegetative as in *Phryma, Ludvigia, Baptisia*, floral in *Chenopodium ambrosioides*, and that the basal internodes of this shoot persist and, with the hypocotyl and root, form a pseudo-rhizome, a complex of stem-bases. Furthermore the plumule may develop into an aerial shoot, of which the cotyledonary buds grow out as stolons at the expense of the entire primary axis, the seedling; this structure occurs, as described above, in several *Labiatae* (*Lycopus, Scutellaria*), in *Hydrocotyle Americana, Circaea, Trientalis*, etc.; in *Triadenum* we have seen that these cotyledonary shoots have tuberous internodes, thus reminding more of a rhizome than a stolon. The stage of hibernation of the cotyledonary shoots, tubers (*Labiatae*, etc.), tuberous branches (*Triadenum*) might thus be mistaken for axes of primary order, although they are strictly lateral. The development of the plumule into a rosette of leaves, for several years preceeding the appearance of an erect, floral shoot as in *Heuchera* and *Cimicifuga*, recurs in *Claytonia*, as mentioned above. But these structures are very different, however. For in *Claytonia* the primary axis remains purely vegetative through the whole life of the plant, representing a monopodium,

while in *Heuchera* the ramification becomes sympodial after the appearance of the first inflorescense. It is interesting to notice that in several of the acaulescent species of *Viola*, *V. papilionacea* for instance, a similar monopodium is represented, and beginning already at the seedling-stage; in these *Violae*, however, the primary axis increases in length, forming a horizontal rhizome, but with the leaves crowded in the manner of a rosette, and with the primary root not persistent. The different growth of the plumule is altogether of significant importance to the future habit of the plant, and as we have seen above, there is frequently a certain correlation to be observed between the structure of the main, the primary, axis and the root-system. Creeping rhizomes have generally slender roots, at least in the Dicotyledones; but in *Tradescantia rosea* and *T. pinetorum* the long, creeping rhizomes bear thick roots, in the latter even fusiform. Large storage-roots are generally characteristic of species with pseudo-rhizomes (*Asclepias, Dahlia, Panax*), or with very short, erect rhizomes s. s. as for instance *Archemora, Cicuta, Erigenia, Aconitum, Uvularia, Orchis, Platanthera,* etc.; they occur also in certain species of *Ludvigia, Oenothera, Oxalis, Claytonia,* and in *Anemonella,* where the subterranean stem is very poorly represented, by the hypocotyl alone in *Ludvigia* and *Oenothera.* We might also call attention to the profuse development of root-shoots in plants that lack the power to spread by means of rhizomes or stolons, but as stated above some few exceptions are known, for instance *Pyrola, Chimaphila* and *Lupinus* in which stolons are well exemplified.

When, on the other hand, the plumule does not become the center of any subterranean structure, but simply developes into an aerial shoot, the perennial habit then becomes established by means of runners (*Antennaria, Saxifraga flagellaris*), or by the shoot itself becoming a creeping plant (*Glechoma, Ranunculus Cymbalaria*). These two structures substitute stolons, but the runners are generally terminated by rosettes of leaves. We have described the singular structure shown by the runners in *Potentilla Canadensis,* where some of the rosettes hibernate in the shape of tubers. This *Potentilla* does not, however, belong to this category of

plants, since it has a distinct rhizome, and the tubers being axillary, not terminal.

In several annual species the habit may become changed to perennial, but not by means of runners or by the stem becoming creeping. In *Linum Virginianum* L. numerous small, leafy shoots become developed at the base of the fruit-bearing shoot; they are mostly adventitious, and several are developed from the hypocotyl. The hibernating stage thus represents a stem-base with a small rosette of green shoots, some of which may develop into floral shoots in the succeeding spring. *Hypericum mutilum* L. (Fig. 46), *H. Canadense* L. and *H. nudicaule* Walt. show a similar structure with basal shoots, frequently branching. We have thus in these species of *Linum* and *Hypericum* a pseudo-rhizome in its simplest form. As mentioned above *Strophostyles umbellata* may persist for three years, the plumule developing into a vegetative shoot in the first year, the cotyledonary buds into floral shoots in the second, while the persisting root-system produces numerous shoots in the third year. *Amphicarpaea monoica* is an annual, although the cotyledonary buds develop into subterranean, branched shoots, showing the structure of stolons, but being terminated by inflorescences of cleistogamous flowers. But in *Cyperus flavescens* L., as it occurs in the vicinity, true stolons are sometimes developed, enabling the plant to persist for at least another year.

These are thus the most important structures, by which the herbs become enabled to persist as perennials. They are structures of very different origin, and they appear in a number of modifications in accordance with the requirements of the plants for existence and multiplication. Likewise the germination, the hibernation and rejuvenation often reveal structures that deviate remarkably from those possessed by genera or species closely allied. The influence of the environment plays, of course, a rôle of great importance, and many of these structures may be readily recognized as epharmonic. But there are others, which are undoubtedly fixed, those that accompany the plant, wherever it grows. The organization, or we might say the individuality, of the plants is the most potent factor, however. It sometimes acts independently of relationship, but in conformity with the re-

quirements of the plant and its plasticity. It seems as if we cannot in any other way explain the occurrence of certain peculiar structures in plants representing a very natural assemblage of genera or species and otherwise possessing all the characteristics of relationship. We have seen how differently the seedlings prepare for the first hibernation, and the complex of structures that evolve in the course of rejuvenation. We need only to remind of the genus *Viola*, how the first hibernation indicates the singular bulbous structure of the rhizome in *V. papilionacea* Pursh and its allies, so very distinct from all the others. From this particular point of view *Viola* is especially interesting. The floral structure is so uniform that Gingius and De Candolle only recognized three sections based upon the direction of the petals in the European species, while Brainerd (Gray's Manual) divided 45 North American species into seven sections according to the structure of the style. But if we combine the floral structure with the habit in the European and North American species (incl. the Pacific States) the number of sections may be increased to eleven. The habit is very characteristic. Most of the caulescent species are perennial with pseudo-rhizomes, runners or stolons, and several show a monopodial growth. In the acaulescent we have the bulbous rhizome represented by the *V. papilionacea* group (*V. emarginata* Le Conte, *V. Macounii* Greene, *V. affinis* Le Conte etc.), beside some few European: *V. umbrosa* Fr., *V. sciaphila* Koch, *V. cyanea* Celak., etc. The other acaulescent species have creeping, very slender rhizomes, stolons or runners, except *V. pedata* L., *V. pedatifida* Don and *V. pinnata* L. in which the stout rhizome is vertical. We have thus in *Viola* an excellent example of a genus with a very uniform structure of the flower and fruit, but with the vegetative reproduction effected in a very different way. In certain species the epharmonic characters are shown by the leaves, notably the ample blades of the aestival foliage of the more or less sciaphilous species and perhaps by the deeply cut leaves of the species in the open. But with reference to the distribution of rhizomes, stolons and runners, these are frequently represented by species growing associated with each other, and may therefore not be regarded as epharmonic. The bulbous rhizome in

Viola is somewhat unique, and in no connection with the other types of stem-structures in the genus. It seems strange that the nearest analogy of this bulb-like structure must be sought in *Dentaria* and *Lithophragma*. In the species of the former tuberous and bulb-like rhizomes are the typical and the only ones represented by the genus.

We might also mention the genus *Stellaria*. In most of the species the vegetative reproduction is effected by means of stolons, but, as described above, *Stellaria pubera* multiplies by aerial shoots becoming runner-like, besides that a pseudo-rhizome becomes developed. In *Stellaria Jamesii* Torr., on the other hand, a typical, creeping rhizome is developed, with the internodes partly swollen and tuberous, resembling sometimes the stolons of *Apios*. Moreover in *Stellaria bulbosa* Wulf., from Austria, the very weak, ascending shoots have a fusiform, fleshy tap-root at each of the subterranean nodes.

Finally we have in *Claytonia* a genus of about only thirty species with a habit so different, that no less than five sections are necessary to combine these in a systematic manner, the distinction depending mainly on purely vegetative characters. A large, persistent primary root is characteristic of *Euclaytonia*, beside the monopodial growth of the shoot. In *Limnia* the species are either annual, or perennial with a horizontally creeping rhizome or with stolons; *Alsinastrum* has bulbiferous stolons; *Naiocrene* has a short, vertical monopodial rhizome, and bulblets are developed in the axils of the cauline leaves; in *Montiastrum* all the species are annual with the leaves broadly ovate to linear. With the exception of some species of *Montiastrum*, where the petals are unequal, and some of the stamens suppressed, the floral structure is very uniform in the genus.

The purely vegetative characters thus constitute a great complex of structures, sometimes very unequally distributed in the natural families of plants. The systematic position of the genus among the more evolute or lesser developed types plays no rôle of importance as to the behavior of the plant during the stage of hibernation and rejuvenation. Combination of structures, cauline or foliar, are not always necessary to the actual outcome of the first hibernation—a lateral root with a bud may be sufficient, as we have seen in *Rhexia*.

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THE FOSSIL FLORA OF THE VICINITY OF COLD SPRING HARBOR.

BACILLARIOPHYTA*

ACHNANTHOIDEAE

Campyloneis Grevillei (W. Sm) Grun. Lloyd Neck, L. I.—H. Ries.
Cocconeis pediculus Ehr. Lloyd Neck, L.I.—H. Ries.
Cocconeis placentula Ehr. Lloyd Neck, L. I.—H. Ries.

BIDDULPHIODEAE.

Triceratium trifoliatum. Lloyd Neck, L. I.—H. Ries.

DISCOIDEAE.

Melosira granulata (Ehrb.) Kuetz. Lloyd Neck, L. I.—H. Ries.
Stephanodiscus niagarae Ehr. Lloyd Neck, L. I.—H. Ries.

FRAGILLAROIDEAE.

Diatoma hiemale K. B. Lloyd Neck, L. I.—H. Ries.
Eunotia monodon Ehr. Lloyd Neck, L. I.—H. Ries.
Fragillaria construans. Gruns.
Synedra affinis Kuetz. Lloyd Neck, L. I.—H. Ries.

NAVICULOIDEAE.

Cymbella cuspidata Kuetz. Lloyd Neck, L. I.—H. Ries.
Cymbella delicatula Kuetz. Lloyd Neck, L. I.—H. Ries.
Encyonema ventricosum Kuetz. Lloyd Neck, L. I.—H. Ries.
Epithema turgida (Ehr.) Kuetz. Lloyd Neck, L. I.—H. Ries.
Gomphonema capitatum Ehrb. Lloyd Neck, L. I.—H. Ries.
Navicula cucconeiformis Greg. Lloyd Neck, L. I.—H. Ries.
Navicula lata Breb. Lloyd Neck, L. I.—H. Ries.
Navicula major Kutz. Lloyd Neck, L. I.—H. Ries.
Navicula varians Grey. Lloyd Neck, L. I.—H. Ries.

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* Compiled from "Microorganisms in the Clays of N. Y." H. Ries, Trans. N. Y. Acad. Science Vol. 13, 1894, p. 165-69.

Navicula viridis Kuetz. Lloyd Neck, L. I.—H. Ries.
Stauroneis phaenecenteron Ehrb. Lloyd Neck, L. I.—H. Ries.

PTERIDOPHYTA*

MARSILIACEAE.

Marsilea Andersoni Hollick. Manhasset—A. E. Anderson.

POLYPODIACEAE.

Onoclea inquirenda (Hollick) n. comb. Glen Cove, Little Neck, Northport Harbor, L. I.—A. Hollick.

SPERMATOPHYTA.

GYMNOSPERMAE.

ARAUCARINAE.

Androvettia statenensis Hollick and Jeffrey, Androvette pit, Kreischerville, Staten Island, E. C. Jeffrey and Hollick.

Anomaspis hispida Hollick and Jeffrey. Androvette pit, Kreischerville, Staten Island—E. Jeffrey and Hollick.

Anomaspis tuberculata Hollick and Jeffrey. Androvette pit, Kreischerville, Staten Island,—E. Jeffrey and A. Hollick.

Araucariopitys americana Jeffrey. Androvette pit, Kreischerville, Staten Island.—E. C. Jeffred and A. Hollick.

Araucarioxylon noveboracense Hollick and Jeffrey. Drummond pit, Kreischerville, Staten Island.—E. C. Jeffrey and A. Hollick.

Brachyoxylon notabile Hollick and Jeffrey. Androvette pit, Kreischerville, Staten Island. A. Hollick and E. C. Jeffrey.

Dactylolepis crytomeroides Hollick and Jeffrey. Androvette pit, Kreischerville, Staten Island. E. C. Jeffrey and A. Hollick.

Eugeinitzia proxima Hollick and Jeffrey. Androvette pit, Kreischerville, Staten Island. E. C. Jeffrey and A. Hollick.

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* This list is compiled from the following publications "The Cretaceous Flora of Southern New York and New England." A. Hollick. Mon. 50: U. S. G. S. 1906; Additions to the Paleobotany of the Cretaceous formation on Long Island No. III. A. Hollick. Bull. N. Y. Bot. Garden. 8:154-170; Studies of Cretaceous Coniferous Remains from Kreischerville, N. Y. Mem. N. Y. Bot. Garden 3:1-76. Species cited in these publications as occurring on Martha's Vineyard are omitted.

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Thuites sp. Androvette pit, Kreischerville, Staten Island.—E.C. Jeffrey, A. Hollick.

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CYCADACEAE.

Podozamites lanceolatus (Lindley and Hutton) Schimper. Glen Cove, L. I. Kings Gravel Pit, Roslyn, N. Y.—A. Hollick.

Podozamites sp. Glen Cove, L. I.—A. Hollick.

Protophyllocadus subintegrifolius (Lesq.) Berry. Black Rock Point, Block Island; Tottenville, Staten Island; Princess Bay, Staten Island.—A. Hollick.

Williamsonia problematica (Newberry) Ward. Glen Cove, N. Y.—A. Hollick, E. Berry, A. B. Bibbins.

FAMILY PINACEAE.

Brachyphyllum macrocarpon Newberry. Little Neck, Northpoint Harbor, Northport Harbor, L. I. A. Hollick; Drummond pit, Kreischerville, Staten Island, J. H. Dunnigan; Androvette pit, Kreischerville, S. C. Jeffrey, A. Hollick.

Cyparissidium gracile (Heer.) Heer. Tottenville, Staten Island—A. Hollick.

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Widdingtonites subtilis Heer. Black Rock Point, Block Island.—A. Hollick.

ANGIOSPERMAE.

Typha sp. Lloyd Neck, L. I.—David White.

POACEAE (*Graminaceae*)

Poacites sp. Glen Cove, L. I.—A. Hollick.

CYPERACEAE.

Cyperacites sp. Glen Cove, L. I.—A. Hollick.

LILIACEAE.

Majanthemophyllom pusillum Heer. Kreischerville, Staten Island.—A. Holilck.

SALICACEAE.

Populus (?) *apiculata* Newberry. Glen Cove, L. I.—David White.

Populus harkeriana Lesq. Tottenville, Staten Island.—A Hollick.

Aments of *Populus* sp. Glen Cove, L. I.—A. Hollick.

Salix cuneata Newberry. Kreischerville, Glen Cove, L. I.—David White.

Salix meekii Newberry. Arrochar, Staten Island.—A. Hollick.

Salix membranacea Newberry. Kreischerville, Staten Island.—A. Hollick.

Salix proteaefolia flexuosa (Newberry) Lesq. Sea Cliff, Long Island.—G. van Ingen.

Salix proteaefolia lanceolata Lesq. Black Rock Point, Block Island; Arrochar, Staten Island.—A. Hollick.

Salix purpuroides Hollick, Sea Cliff, L. I.—G. van Ingen.

Salix sp. Kreischerville, Staten Island.—A. Hollick.

MYRICACEAE.

Myrica Davisii, Hollick. Kreischerville. Staten Island.—W. T. Davis.

Myrica Hollicki Ward. Tottenville, Staten Island.—A. Hollick.

Myrica Zenkeri (Ettinghausen) Velenousky. Glen Cove, L. I.—David White.

JUGLANDACEAE.

Juglans arctica Heer. Tottenville and Staten Island, Black Rock Point, Block Island; King's Gravel Pit, Roslyn; Glen Cove, L. I.—A. Hollick.

Juglans crassipes Heer. King's Gravel Pit, Roslyn, L. I.—A. Hollick.

Juglans elongata Hollick. Sea Cliff, L. I.—G. Van Ingen.

FAGACEAE.

Quercus morrisoniana Lesq. Center Island, L. I.—A. Hollick.
Quercus (?) *novae-caesareae* Hollick. Tottenville, Staten Island—A. Hollick.

MORACEAE.

Kings Gravel Pit, Roslyn.

Ficus atavina Heer. Glen Cove, L. I.—A. Hollick.
Ficus fracta Velenovsky. Oak Neck, L. I.—A. Hollick.
Ficus Krausiana Heer. Southeast Point, Block Island.—A. Hollick.
Ficus Krausiana var. *susibmilis* Hollick. Kings Gravel Pit, L. I.—A. Hollick.
Ficus myricoides Hollick. Glen Cove, L. I.—David White.
Ficus sapindifolia Hollick. Mott Point, Manhasset Neck, L. I. —A. E. Anderson.
Ficus willisiana Hollick. Sea Cliff, L. I., G. van Ingens' Glen Cove,—A. Hollick.
Ficus Woolsoni Newberry. Kreischerville, Tottenville, Staten Island, Glen Cove, L. I.—A. Hollick, E. W. Berry, A. Bibbins.

PROTEACEAE.

Banksites saportanus Velenovsky. Glen Cove, L. I.—A. Hollick.
Embothriopsis presagita Hollick. Glen Cove, L. I.—A. Hollick, E. W. Berry, A. Bibbins.
Proteoides daphnogenoides Heer. Sea Cliff, L. I.—G. van Ingen.

NYMPHACEAE.

Nelumbo Kempii (Hollick) Hollick. King's Gravel Pit, Roslyn; Glen Cove, L. I., A. Hollick; Manhasset Neck, L. I. —A. E. Anderson.

MENISPERMACEAE.

Cocculus minutes Hollick. Little Neck, Northport Harbor, L.I.—H. Ries.
Menispermites Brysoniana Hollick. Glen Cove, L. I.—A. Hollick.
Menispermites sp. Tottenville, Staten Island, Hollick.

MAGNOLIACEAE.

Magnolia alternans Heer. Elm Point, Great Neck, L. I. — Pollard.

Magnolia auriculata Newberry. Glen Cove, L. I.—A. Hollick.

Magnolia Capellinii Heer. Glen Cove, Center Island, L. I.— A. Hollick.

Magnolia glaucoides Newberry (?) Sea Cliff, L. I.—G. van Ingen.

Magnolia Isbergiana Heer. Glen Cove, L. I.—A. Hollick.

Magnolia longifolia Newberry. Tottenville, Staten Island.— A. Hollick.

Magnolia longipes Newb. King's Gravel Pit, Roslyn, Glen Cove, L. I.—A. Hollick, Dosoris Island, L. I.—B. Willis.

Magnolia speciosa Heer. Glen Cove, L. I.—A. Hollick.

Magnolia tenuifolia Lesq. Sea Cliff. G. van Ingen. Glen Cove—David White.

Magnolia Van Ingeni Hollick. King's Gravel Pit, Roslyn; Sea Cliff, L. I.—G. van Ingen.

Magnolia woodbridgensis Hollick. King's Gravel Pit, Roslyn; Balls Point, Block Island.—A. Hollick.

Liriodendron attenuatum Hollick Glen Cove, L.I.—A. Hollick.

Liriodendron oblongifolium Newberry, Glen Cove.—A. Hollick.

Liriodendron primaevum Newberry. Tottenville, Staten Island.—A. Hollick.

Liriodendropsis angustifolia Newberry. Glen Cove, L. I.—D. White.

Liriodendropsis constricta (Ward var.) Glen Cove, L. I.— A. Hollick.

Liriodendropsis retusa (Heer) Glen Cove, L. I.—A. Hollick.

Liriodendropsis simplex (Newberry) Newberry. Glen Cove, L. I.—David White and A. Hollick.

Liriondendropsis spectabilis Hollick. Glen Cove.—D. White and A. Hollick.

ANONACEAE.

Guatteria cretaceae Hollick. Glen Cove, L. I.—D. White.

LAURACEAE.

Cinnamomum crassipetiolatum Hollick. Glen Cove. L. I. — D. White.

Cinnamomum intermedium Newberry. Manhasset Neck, Glen Cove, Sea Cliff, L. I.—A. Hollick.

Cinnamomum membranaceum (Lesq) Hollick. Glen Cove, L. I.—A. Hollick.

Laurophyllum elegans n. s. Glen Cove, L. I.—A. Hollick.

Laurophyllum lanceolatum Newberry. Glen Cove, L. I.—A. Hollick, E. Berry, A. Bibbins.

Laurophyllum nervillosum Hollick. Tottenville, Staten Island. —A. Hollick.

Laurophyllum ocoteaoides Hollick. Glen Cove, L.I.—A. Hollick.

Laurus augusta Heer. Little Neck, Northport Harbor, L. I. —H. Ries.

Laurus antecedens Lesq. Glen Cove, L. I.—D. White.

Laurus Hollae Heer. Kreischerville, Staten Island.—A. Hollick.

Laurus nebrascensis (Lesq.) Lesq. Kreischerville, Tottenville, Staten Island.—A. Hollick.

Laurus Newberryana Hollick. Glen Cove, L. I.—A. Hollick.

Laurus plutonia Heer. King's Gravel Pit, Roslyn, Black Rock Point, Block Island, A. Hollick; Glen Cove, L.I., D. White; Sea Cliff, L.I., G. van Ingen.

Ocotea nassavensis Hollick. Glen Cove.—D. White.

Persea Valida Hollick. Glen Cove,—D. White.

Platanus aquehongensis Hollick. Richmond Valley, Staten Island.—Mesner.

Platanus (?) *Newberryana* Heer. Elm Point, Great Neck, L. I.—Pollard.

Platanus sp. Princess Bay, Staten Island.—A. Hollick.

Sassafras acutilobum Lesq. King's Gravel Pit, Roslyn, Glen Cove, L. I.—A. Hollick.

Sassafras hastatum Newberry. Glen Cove, L. I.—A. Hollick.

Sassafras progenitor Newberry. Oak Neck, L. I.—A. Hollick.

CAESALPINACEAE.

Cassia insularis Hollick. Glen Cove, L. I.—A. Hollick, E. Berry, A. Bibbins.

Liriodendropsis constricta (Ward) Hollick. Glen Cove, L. I. A. Hollick.

Liriodendropsis gimplex (Newberry) Newberry. King's Gravel Pit. Roslyn, L. I.

Hymenaea dakotana Lesq. Sea Cliff, G. van Ingen. Lloyd Neck — A. Hollick.

PAPILIONACEAE.

Colutea primordialis Heer. Eaton Neck, L. I.—A. Hollick.
Dalbergia hyperborea Heer. Tottenville, Staten Island—A. Hollick.
Phaseolites elegans Hollick. Brooklyn, L. I.—Hollick.
Phaseolites manhassettensis Hollick. Manhasset Neck, L. I. —A. E. Anderson.

OTHER LEGUMINOSAE.

Leguminosites convolutus Lesq. Glen Cove.—A. Hollick.
Leguminosites constrictus Lesq. Oak Neck, L. I.—A. Hollick.
Leguminosites coronilloides Heer. Kreischerville, Staten Island.—A. Hollick.

ANACARDIACEAE.

Pistacia aquebongensis Hollick. Tottenville, Staten Island. —A. Hollick.
Rhus cretacea Heer I. Glen Cove, L. I.—D. White.

CELASTRACEAE.

Celastrophyllum crassipes Lesquereux (?) King's Gravel Pit, Roslyn, New York.—A. Hollick.
Celastrus arctica Heer. Little Neck. (Northport Harbor) L. I.—A. Hollick.
Elaeodendron sp. Glen Cove, L. I.—A. Hollick.

ACERACEAE.

Acer minutum Hollick. Tottenville, Staten Island.—A. Hollick.

SAPINDACEAE.

Sapindus apiculatus Velenovsky, Glen Cove, L. I.—D. White.
Sapindus imperfectus Hollick. Manhasset Neck, L. I.—A.E. Anderson.
Sapindus morrisoni Lesq. Glen Cove, L. I.—A. Hollick.

RHAMNACEAE.

Ceanothus constrictus Hollick. Glen Cove.—D. White.
Paliurus affinus Heer. Tottenville, Kreischerville, Staten Island.—A. Hollick.

Paliurus integrifolius Hollick. Oak Neck, Lloyd Neck, Glen Cove.—A. Hollick; Little Neck, Northport Harbor,— H. Ries.

Rhamnus acuta Heer. Lolyd Neck, L. I.—A. Hollick.

Zizyphus elegans Hollick, Glen Cove, L. I.—A. Hollick.

Zizyphus Lewisiana Hollick. Oak Neck, L. I.—A. Hollick.

Zizyphus oblongus Hollick. Glen Cove.—A. Hollick.

VITACEAE.

Cissites formosus Heer. Dosoris Island, Long Island. — B. Willis.

STERCULIACEAE.

Pterospermites modestus Lesq. Tottenville, Staten Island.—A. Hollick.

Sterculia sp. Tottenville, Staten Island.—A. Hollick.

MYRTACEAE.

Eucalyptus angustifolia Newberry. Little Neck, Northport Harbor, L. I.—A. Holilck.

Eucalyptus Geinitzii (Heer.) Heer. King's Gravel Pit, Roslyn; Glen Cove, L. I.—A. Hollick.

Eucalyptus Geinitzii propinqua Hollick. King's Gravel Pit, Roslyn, L. I.—A. Hollick.

Eucalyptus latifolia Hollick. Glen Cove, L. I.—A. Hollick.

Eucalyptus (?) *nervosa* Newberry. Sea Cliff, L. I.—G. van Ingen.

Myrtophyllum sapindoides Hollick. Glen Cove, L. I.—A. Hollick.

Myrtophyllum Warderi Lesq. Glen Cove, L. I.—A. Hollick.

ARALIACEAE.

Aralia nassauensis Hollick. Brooklyn, L. I.—J. C. Brevoort.

Aralia palmata Newberry. Tottenville, Staten Island, A. Hollick.

Aralia patens Newberry? Glen Cove, L. I.—A. Hollick.

Aralia Ravniana Heer. Tottenville, Staten Island.—A. Hollick.

Chondrophyllum orbiculatum Heer. Kreischerville, Staten Island.—A. Hollick.

OLEACEAE.

Ligustrum subtile Hollick. King's Gravel Pit, Roslyn, L. I. —A. Hollick.

ERICACEAE.

Andromeda latifolia Newberry. Oak Neck, L. I.—A. Hollick.
Andromeda Parlatorii Heer. Glen Cove, L. I.—A. Horlick.
Andromeda tenuinervis Lesq. Tottenville, Staten Island.—A. Hollick.
Kalmia brittoniana Hollick. Kreischerville, Staten Island.—A. Hollick.

MYRSINACEAE.

Myrsine borealis Heer. Glen Cove, L. I.—A. Hollick.
Myrsine elongata Newberry. Lloyd Neck, L. I.—A. Hollick.
Myrsinites (?) *Gaudini* Lesq. Tottenville, Staten Island.—A. Hollick.

EBENACEAE.

Diospyros apiculata Lesq. Glen Cove, L. I.—David White.
Diospyros primaeva Heer. Glen Cove, L. I.—David White.
Diospyros prodromus Heer. Glen Cove, L. I.—D. White.
Diospyros provecta Velenovsky. Tottenville, Staten Island. —A. Hollick.
Diospyros pseudoanceps Lesq. Glen Cove, L. I.—A. Hollick.

CAPRIFOLIACEAE.

Viburnum hollickii Berry. Lloyd Neck, L. I.—A. Hollick.
Viburnum integrifolium Newberry. Glen Cove, L. I.—A. Hollick.

OTHER DICOTYLEDONES

Dewalquea gronlandica Heer? Tottenville, Staten Island.—A. Hollick.
Dewalquea insignis Hosius and von der Marck. Kreischerville, Staten Island.—A. Hollick.
Phyllites poinsettioides Hollick. Kreischerville, Staten Island. —A. Hollick.
Premnophyllon trigonum Velenovsky. Glen Cove, L. I.—A. Hollick.

INCERTAE SEDIS.

Calycites alatus Hollick. Montouk Point, L. I.—A. Hollick.
Carpolithus evonymoides Hollick. Tottenville, Staten Island. —A. Hollick.

Carpolithus vaccinioides Hollick. Kreischerville, Staten Island.—A. Hollick.

Carpolithus sp. 5 undetermined species from Green Ridge and Kreisecherville, Staten Island.—A. Hollick.

Credneria macrophylla Heer. King's gravel pit, Roslyn, New York.—A. Hollick.

Rhizomorphs. In hard clay ironstones at Tottenville, Staten Island.—A. Hollick.

Tricalycites major Hollick. King's Gravel Pit, Roslyn, Glen Cove, L. I.—A. Hollick.

Tricalycites papyraceus Newberry. Lloyd Neck.—A. Hollick.

Williamsonia Riesii Hollick. Kreischerville, Staten Island.—A. Hollick.

INSECT GALLS.

Burnham and Latham (1914-24) list the following insect galls from their Flora of the Town of Southold, Long Island, and Gardiners Island. Doubtless many of them may be found further west along the coast in the vicinity of Cold Spring Harbor.

Acarus Serotinae Beutm.—Wild Cherry Pouch Gall.

Acraspis erinacei Walsh.—Oak Hedgehog Gall.

Amphibolips acuminata Ashm.—Very abundant on *Quercus ilicifolia* at Laurel, L. I.

Amphibolips confluentus Harr.—Oak Apple.

Andricus cornigerus O. S.—Horned Knot Oak Gall.

Andricus futilis O. S.—Oak Wart Gall on leaves of *Quercus alba.*

A. palustris O. S.—Succulent Oak Gall on leaves of *Quercus palustris.*

A. petiolicola Bass.—Oak Petiole Gall on leaves of *Quercus alba* and *Q. velutina.*

A. punctatus Bass.—Oak Knot Gall.

A.seminator Harr.—Oak Seed Gall.

Asphondylia globosus O. S.—On stems of *Helianthus divaricatus.*

Asteromyia carbonifera Felt.—On leaves of Euthamia tenuifolia.

Asteromyia rubra Felt.—On leaves of *Solidago bicolor.*

Aulax tumidus Bass.—Lettuce Tumor Gall.

Biorhiza forticornis Walsh.—Oak Fig Gall on twigs of *Quercus alba.*

Caryomyia tubicola O. S.—On leaves of *Hicoria glabra* at Cutchogue, L. I.

Cecidomyia Caryaecola O. S.—Hickory Seed Gall.

C. holotricha O. S.—Hickory Onion Gall.

C. niveipila O. S.—Oak Fold Gall.

Cecidomyia verrucicola O. S.—On leaves of *Tilia americana* at Southold, L. I.

C. Nyssaecola Beutm.—On leaves of *Nyssa sylvatica.*

C. (?) *ocellaris* Comstock— Maple Spot Gall on leaves of *Acer rubrum.*

C. sanguinolenta O. S.— Hickory Cone Gall.

C. Serotinae O. S.—Wild Cherry Bud Gall.

Cinsticornia pilulae Walsh.—Oak Pill Gall on leaves of *Quercus velutina.*

Cecidomya viticola O.S.—On leaves in *Vitis* at Mattituck.

Cynips Pisum Fitch—Oak Pea Gall.

Cystiphora canadensis Felt.—On leaves of *Nabalus.*

C. viburnifolia Felt.—On leaves of *Viburnum acerifolium* and *V. dentatum.*

Dasyneura Galii Felt.—On flower buds of *Galium.*

Dasyneura Yysmachiae Beutm.—On *Lysimachia quadrifolia* at Orient, L. I.

D. Salicifolia Felt.—On young willow leaves.

Diastrophus Cuscutaeformis O. S.—Blackberry Seed Gall.

D. nebulosus O. S.—Blackberry Knot Gall.

D. niger Bass.—On leaves of *Potentilla canadensis.*

Disholcaspis gamma Walsh.—On twigs of *Quercus velutina* at Greenport, L. I.

Diastrophus Potentillae Bass.—Cinquefoil Axil Gall; on stems of *Potentilla Canadensis.*

Dryophanta polita Bass.—Polished Oak Gall.

Erineum fagineum Pers.—Beechleaf Mite Gall.

Eriophyes abnormis Garman—A mite gall on leaves of *Tilia americana.*

Eriophyes Cephalanthi Cook.—Greenport on leaves of *Cephalanthus occidentalis.*

E. Nyssae Trotter.—On leaves of *Nyssa sylvatica.*

E. Querci Garman.—On leaves of *Quercus velutina.*

E. semen Walsh.—Orient on leaves of *Salix.*

Gnorimaschema gallaesilodaginis Riley—On stems of *Solidago serotina.*

Holcaspis globulus Fitch.—Oak Bullet Gall.

Hormaphis Hamamelidis Fitch.—Witch Hazel Cone Gall.

H. spinosus Shiner.—Spiny Witch Hazel Gall.

Hormomyia canadensis Felt.—Cutchogue on leaves of *Amelanchier oblongifolia.*

Hormomyia Crataegifolia Felt.—On leaves of *Crataegus.*

Itonida foliora Russ & Hock.—On margin of leaves of *Quercus velutina.*

Lasioptera clavula Beutm.—On twigs of *Cornus* at Cutchogue, Greenport and Southold, L. I.

Lasioptera farinosa Beutm.—On leaf veins of *Rubus.*

L. Lycopi Felt.—On stems of *Lycopus.*

L. nodulosa Beutm.—Orient on stems of *Rubus.*

L. virginica Felt.—On stems of *Triadenum virginicum.*

L. Vitis O. S.—Grapevine Tomato Gall.

Livia maculipennis Fitch.—On the inflorescence of *Juncus canadensis.*

Nematus pomum Walsh.—Willow Apple Gall.

Neolasioptera Erigerontis Felt.—On stems of *Leptilon candense.*

Neloasioptera ramuscula Beutm.— On stems of *Doellingeria umbellata* at Orient, L. I.

N. vitinea Felt.—On petioles of grape leaves.

Neuroterus batatus Fitch—Oak Potato Gall on twigs of *Quercus alba.*

N. majalis Bass.—On leaves of *Quercus alba.*

Obolodiplosis Robiniae Hald.—On leaves of Robinia *Pseudo-Acacia.*

Neuroterus noxosus Bass. — Leaves of *Quercus Prisus* at Greenport.

Oligotrophus salicifolius Felt.—On leaves of *Robinia pseudo-acacia.*

Pachypsylla Celtidis-gemma Riley.—Hackberry Nodule Gall.

P. Celtidis-mamma Riley.—Hackberry Nipple Gall.

Pemphigus Populicaulis Fitch.—Popular Stem Gall.

P. Rhois Fitch.—Summac Tomato Gall on leaves of *Rhus glabra.*

Phylloxera Caryaecaulis Fitch.—Hickory Louse Gall.
P. Caryae-globuli Walsh.
Phylloxera Caryaesemen Walsh.—Orient on the under surface of the leaves of *Hicoria glabra.*
P. vastatrix Planch.—Grape Phylloxera.
P. vitifolia Fitch.
Phytophaga rigidae O. S.—On leaves of *Salix discolor* at Southold, L. I.
Phyllocoptes quadripes Shim.—Leaves of *Acer rubrum* at Greenport.
Rhabdophaga Salicifolia Felt.—On leaves of Spirea latifolia.
Rhabdophaga strobiloides Walsh.—On the tips of branches of Salix humilis at Peconic, L. I.
Rhodites bicolor Harr.—Spiny Rose Gall.
R. dichlocerus Harr.—Long Rose Gall.
R. globosus Beutm.—Globular Rose Gall.
R. ignota O. S.—Mealy Rose Gall.
R. verna O. S.—Knotty Rose Gall.
Rhopalomyia anthophila O. S.—On leaves of *Solidago.*
R. capitata Felt.—On stems of *Solidago.*
Rhopalomyia hirtipes O. S.—On aerial stems of *Solidago juncea* at Cutchogue and Peconic, L. I.
R. lateriflora Felt.—On stems of *Aster ericoides.*
R. racemicola O. S.—On flowers of *Solidago rugosa.*
Sackenomyia viburnifolia Felt.—On leaves of *Viburnum dentatum.*
Rhopalomyia Solidaginis Loew.—Goldenrod Bunch Gall.
Solenozopheria Vaccinii Ashm.—Huskleberry Gall on stems of *Gaylussacia baccata.*
Trypeta polita Lw.— Goldenrod Gall.
Trypeta Solidaginis Fitch.—Goldenrod Ball Gall.

BOOK REVIEWS

In this section are reviews of new, or particularly important and interesting books in the fields of natural science. Books dealing with botany or kindred subjects should be sent to the Editor, the University of Notre Dame. *All other books for review* should be sent to Carroll Lane Fenton, at the Walker Museum, the University of Chicago, Ill. Publishers are requested to furnish prices with books.

IMMS, A. D., M. A., D.Sc. A general Textbook of Entomology including the anatomy, physiology, development and classification of insects. E. P. Dutton and Co., New York. 698 pp. Price, $12.00.

The literature on entomology, already voluminous, is steadily growing. There are books on all the orders of insects and inumerable monographs on genera and species. But there was room for a volume that should comprehend the three-fold aspects of the whole subject,—structural, functional and developmental, and taxonomic. The present work is an attempt to produce such a volume. The attempt has been successful, and the author is to be congratulated on having given us a book that leaves nothing to be desired. Ripe, constructive scholarship is the keynote of the work. We know of no book in English where so much that is new has been collected and presented in so scholarly a manner. Condensation becomes an important factor in a book of this kind. But we have nowhere noted that brevity has been attained at the cost of completeness.

The first 157 pages of the book are devoted to a general treatment of insect morphology, the next 50 pages deal with insect embryology, and the remainder of the book—some 470 pages—give a careful review of the orders of insects. A feature that will be especially appreciated by the research student is the series of classified bibliographies at the end of the sections. These include all the more important original works on entomology.

There is a good table of contents, an authors' index and a complete general index. While the book seems to be intended for the specialist in entomology, the teacher or the research worker, it will be found useful for the general reader and certainly indispensible in every college and university library. —F. W.

A GUIDE TO THE TREES, By Dr. Carlton C. Curtis, Professor of Botany, Columbia University.

The best thing we can think of saying of any book is that it perfectly fulfils the purpose for which it was intended and we can claim this of this little volume. Tried on a young city boy that literally did not know one tree from another he succeeded after two or three attempts to determine any of them in a few minutes. Better still it

created a wholesome interest which is the main thing in self-education, and all education is best self made. We think it ought to be as much a part of the equipment of every boy scout and scout master as an ax or knife. It may incite them to use these less on our trees, and the other more to the boy's and community's greater advantage.

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